Search for Higgs in LeptoSusy models

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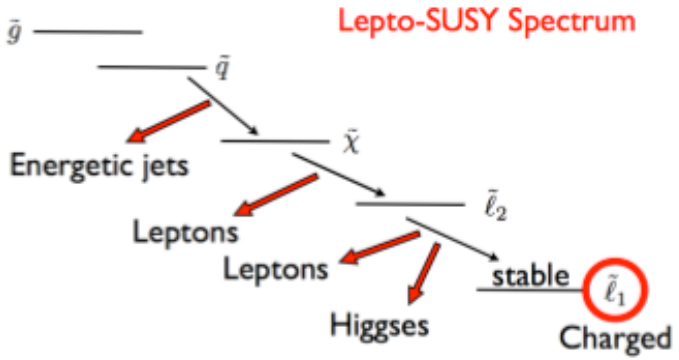
The model

- Leptogenic Supersymmetry
  - SUSY scenario characterized by cascade decays with copious lepton production;
  - Striking signatures that can be probed with just 200 pb^{-1} at LHC 10TeV
    - Long-lived sleptons
    - Several Isolated leptons
    - Energetic jets
    - No MET
    - Copious Higgs production…



V.Sanz et al. Phys.Rev.D80:035010,2009.

The model (cont'd)

Input	m_3	2000 GeV		
	n_1	4.8		
	n_2	3.9		
	n_3	2.2		
	n_4	6.7		
	$\tan\beta$	10		
	sgnμ	+		
Output (GeV)	$m_{\tilde{g}}$	1938	$m_{\tilde{u}_L}$	949
	$m_{\tilde{\chi}_1^\pm}$	291	$m_{\tilde{u}_R}$	920
	$m_{\tilde{\chi}_2^\pm}$	676	$m_{\tilde{d}_L}$	952
	$m_{\tilde{\chi}_4^0}$	676	$m_{\tilde{d}_R}$	919
	$m_{\tilde{\chi}_3^0}$	353	$m_{\tilde{t}_1}$	920
	$m_{\tilde{\chi}_2^0}$	302	$m_{\tilde{t}_2}$	962
	$m_{\tilde{\chi}_1^0}$	271	$m_{\tilde{\ell}_L}$	248
	m_h	115	$m_{\tilde{\ell}_R}$	108
	$m_{H^\pm}$	387	$m_{\tilde{\nu}}$	236
	m_A	379	$m_{\tilde{\tau}_1}$	106
	m_{H_0}	379	$m_{\tilde{\tau}_2}$	249

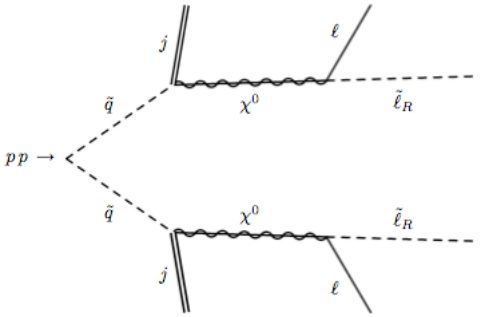
Table 1: A sample spectrum calculated with SUSY-HIT.

Final State topologies with no Higgs

Main Production mechanism: pair production of squarks $pp \to \tilde{q}\bar{\tilde{q}}\,, \tilde{q}\,\tilde{q}$

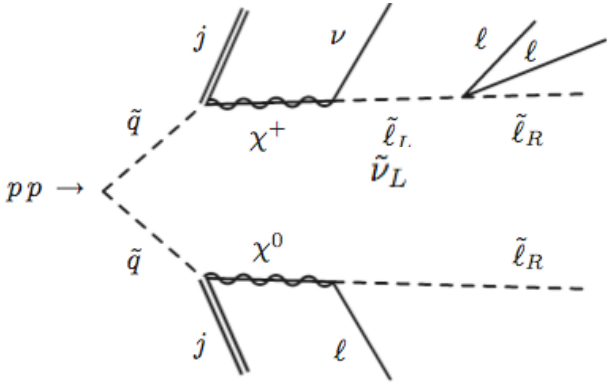
Four-Lepton Channels

Both gauginos decay to stable sleptons and leptons



Five-Lepton Channels

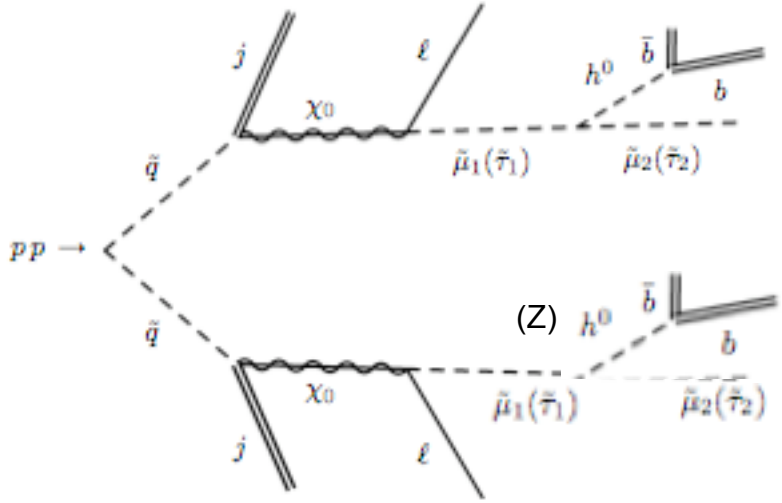
Long decay chain for charginos decaying to stable sleptons and leptons



Six-Leptons when combining the two above

Higgs production and decay

- The SM-Higgs boson in this scenario is light enough to not decay into WW;
- It decays predominantly into bbar (Br = 80%)
- Higgs is produced in cascade decays and it's free of most of the SM background
  - Clean bbbar invariant mass distribution study



Sample

- Using a special file from Veronica, we generated events in the Athena environment and studied them at generator level and at jet level using the JetTruthCollection

- These studies were considered necessary before submitting a request for a large sample through the central production service

- Athena> csc_evgen08new_trf.py 000001 1 5000 1234 MC8.000001.MadGraphPythia.py test.root NONE NONE MadGraph.000001.test._00001.events.tar.gz NONE
  - Pythia only does PS, the generation of leptoSusy is left to Madgraph

- We analyzed two samples:
  - One with only Higgs production;
  - One with all processes (which represents the background)

Events

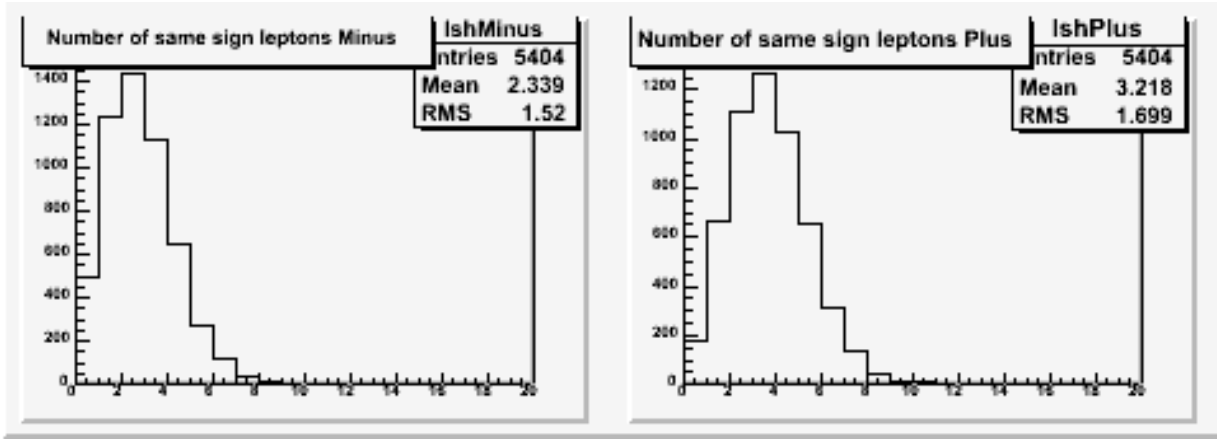
- All the events contain a combination of the following particles in the final state:
  - eR (code 2000011)
  - mu2 (code 2000013)
  - ta1 (code 1000015)
  - Electrons (11) muons (13) and taus (15)
  - In the “signal” sample all events contain at least one bbar pair;
    - All events contain 1 or 2 Higgses (1 or 0 Z’s)

$$\mathrm{BR}(\tilde{\mu}_1 \to h^0(Z) + \tilde{\mu}_2) = 44.1\%\,(35.1\%)$$
$$\mathrm{BR}(\tilde{\tau}_1 \to h^0(Z) + \tilde{\tau}_2) = 53.3\%\,(46.6\%)$$

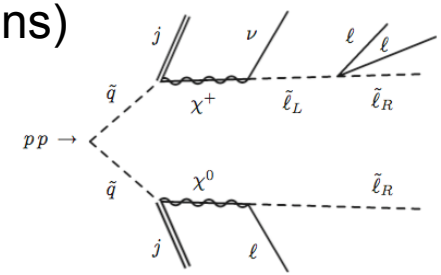
Studies

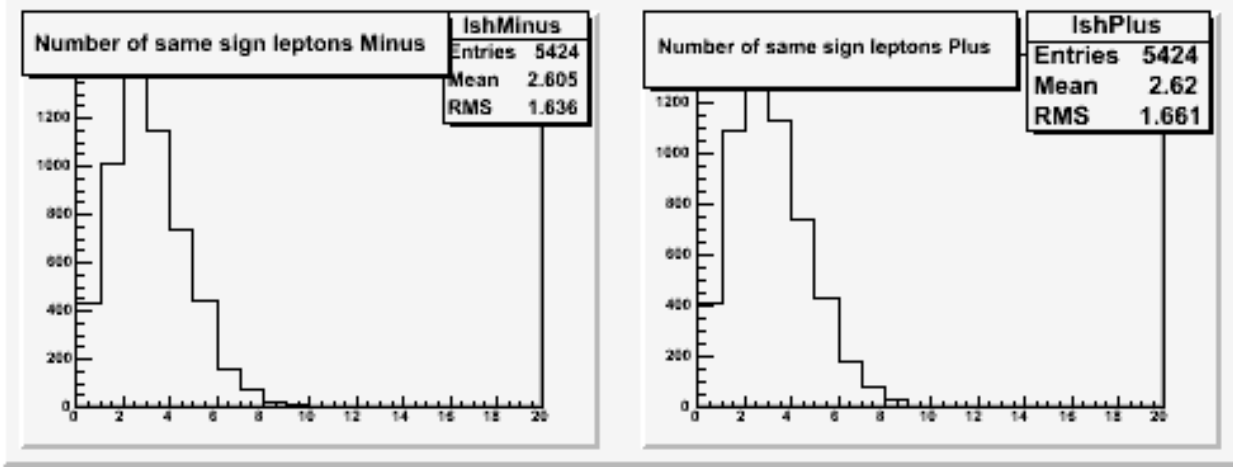
- Check leptons and sleptons multiplicity
  - Co-sleptons scenario - our final sample will only include staus in the final state
- Check the Higgs mass reconstructed from the b-partons
  - Select b's and check for their mother
  - Select Higgs and check for its children
    - Same result in both procedures
- Reconstructed mass of third and fourth jet (as from the theory paper)
  - Mass way higher
  - High jet multiplicity (too high)
  - Run with cone 0.7
    - multiplicity still high
  - Select jets matched to b's in DeltaR and plots their reco mass
    - Mass structure observed.
  - TruthJet multiplicity and removing the "slepton-jets"

Lepton multiplicities

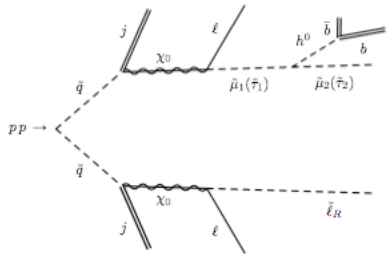


All-Processes
The asymmetry is expected
(three-body decay of sleptons)



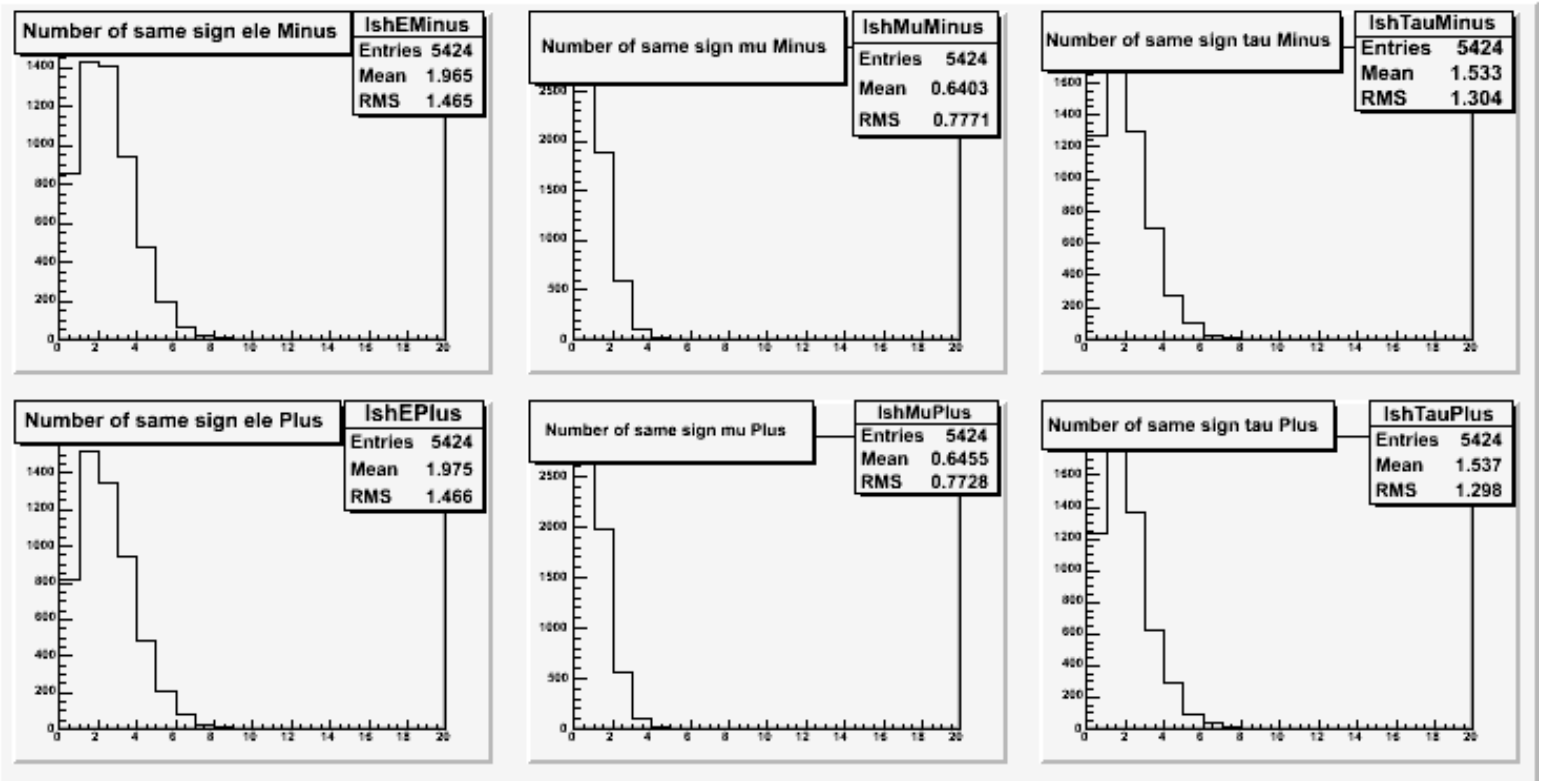


Higgs-only



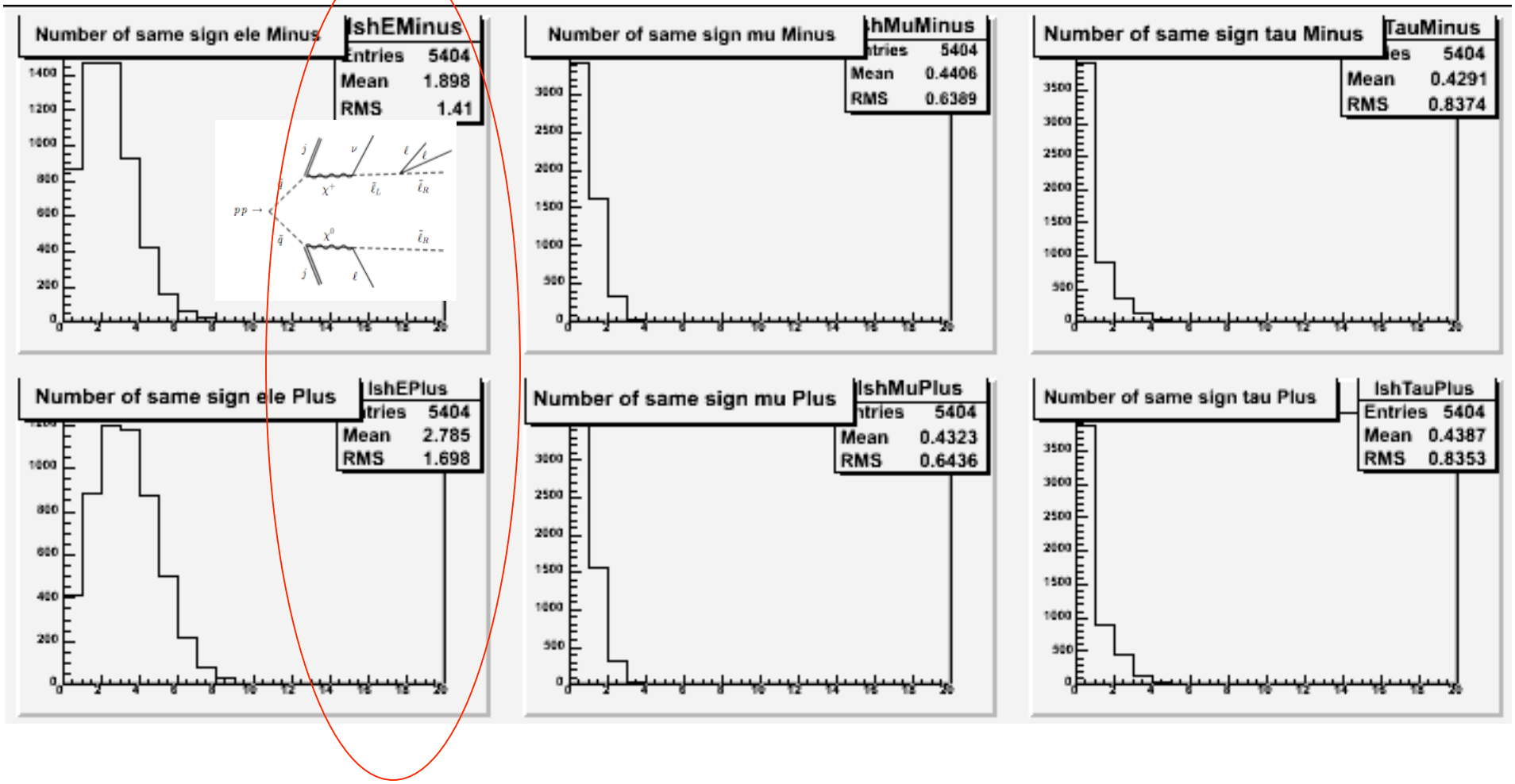
Number of same sign leptons (flavor blind)

Same Sign Leptons (cont'd)



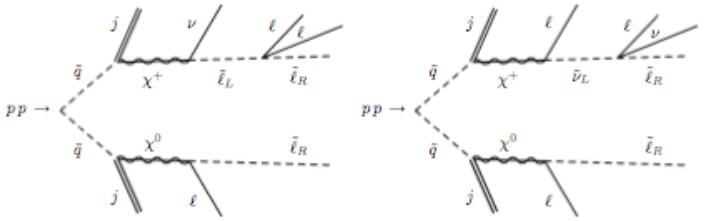
Higgs Only

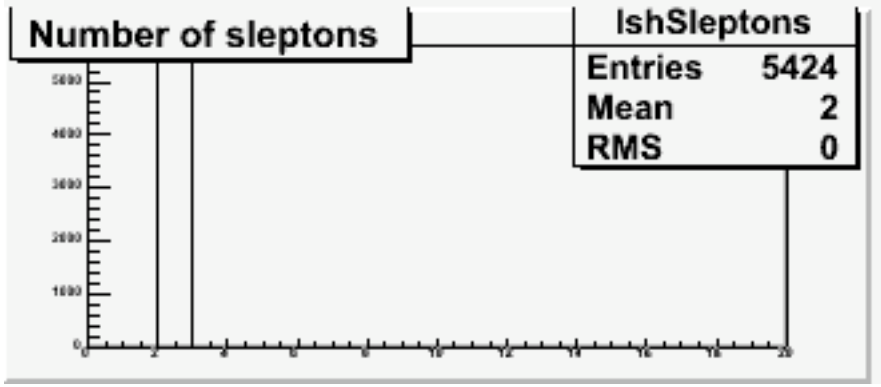
Same Sign leptons (cont'd)

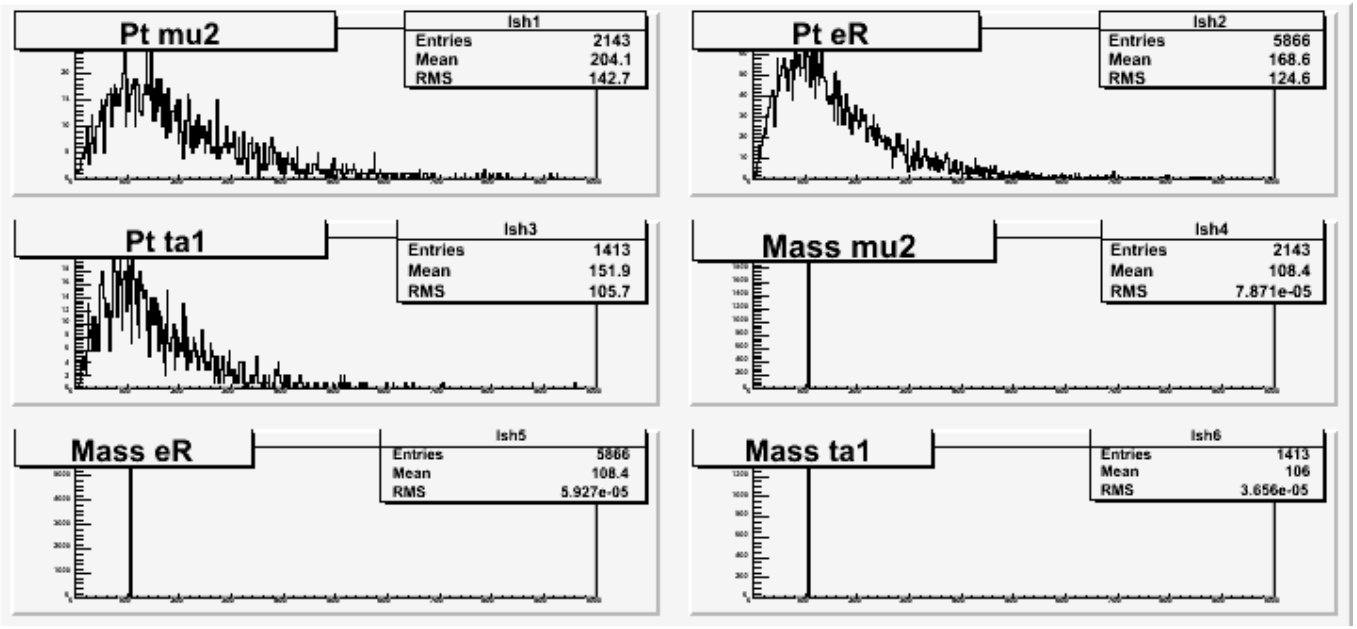


Sleptons multiplicity

Two for each event



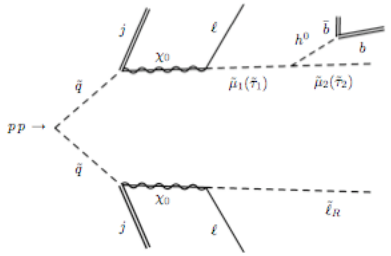


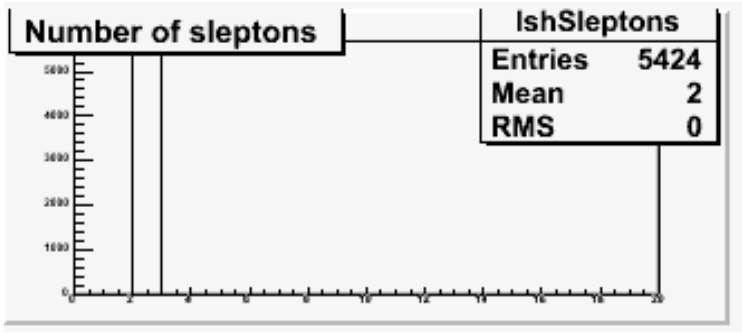


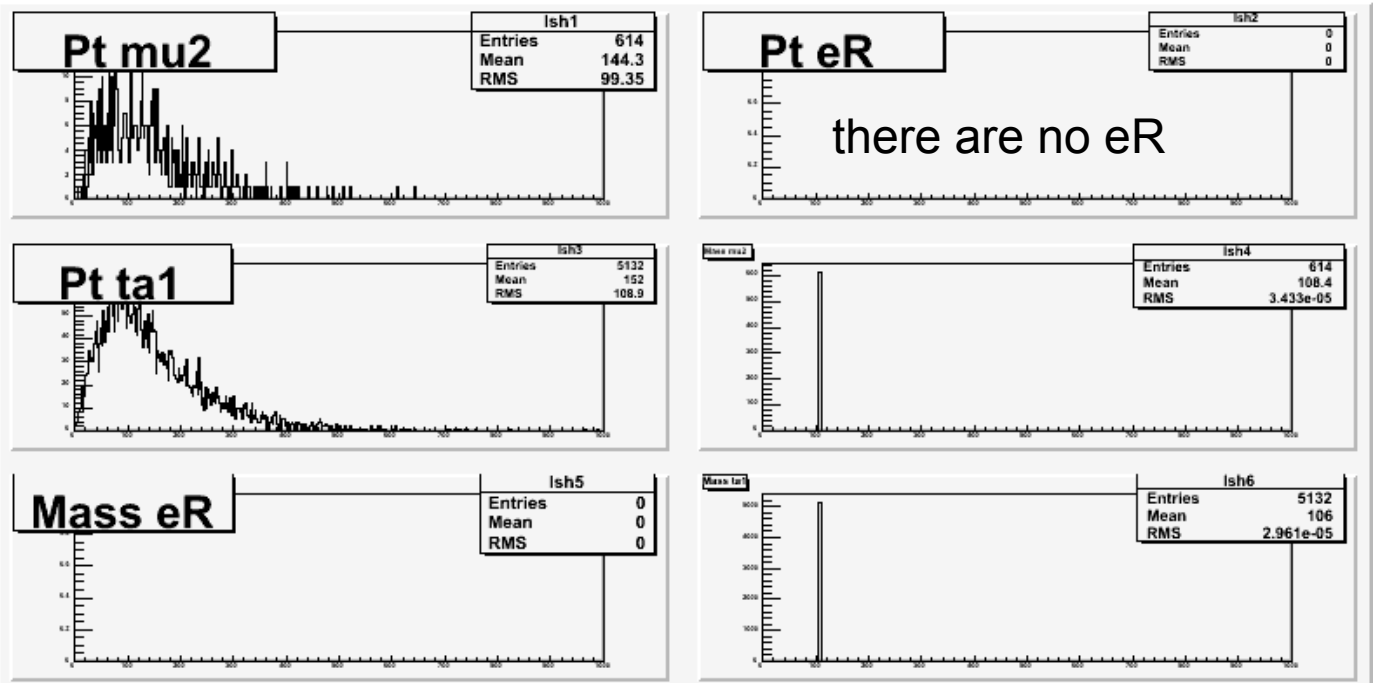
All Processes
(eR is not present in events with Higgs production)

Sleptons Multiplicity

Higgs-only sample

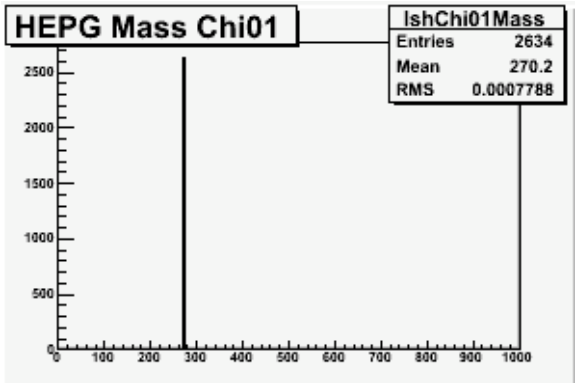


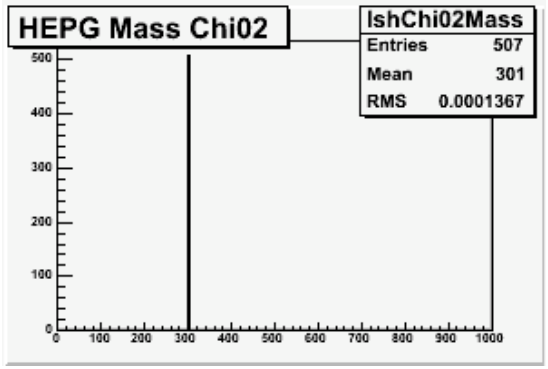


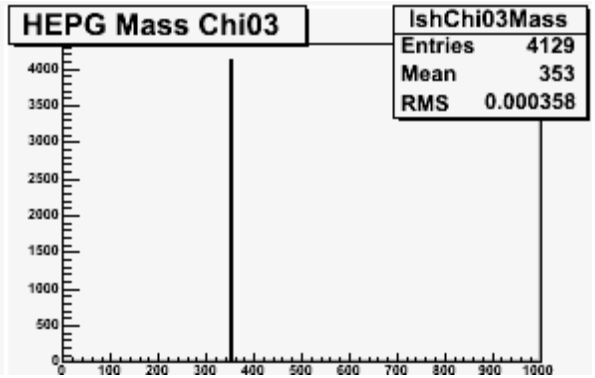


Gaugino Masses

Generator Level:
Neutralinos are selected with status code 3 (hard process particle) to plot their mass at generator level:
chi0_1(270),chi0_2(301),chi0_3(353)



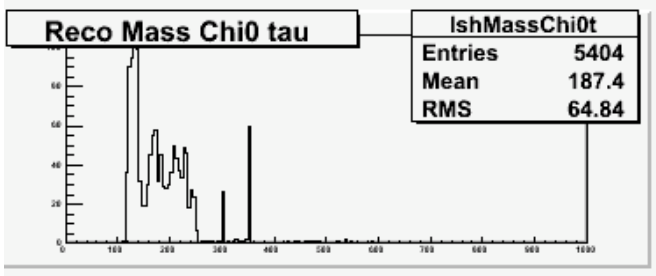




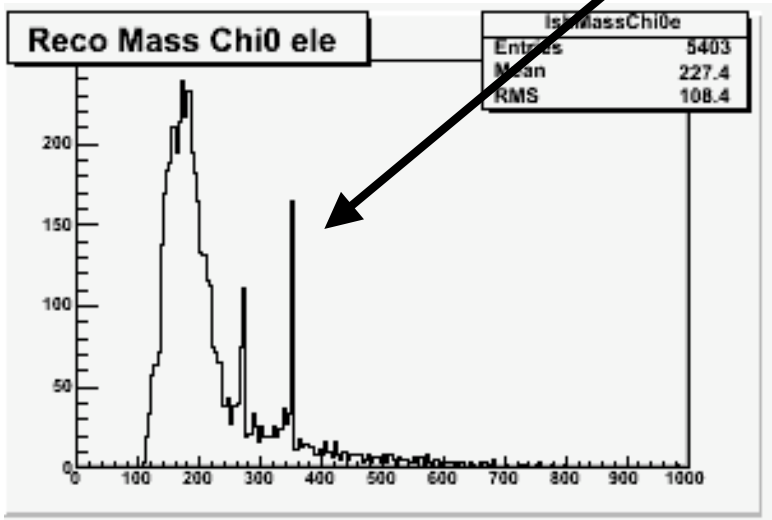
Gaugino Masses

Reconstructed from decay products
Selection:
- Loop on nhep, look for particle with code 2000011 (eR/-eR)
If found, loop on nhep and look for electron (opposite sign to eR)
Since there seem to be several electrons in an event, select the first on the list
Plot invariant mass (eR-e)
- Same for mu2-mu and ta1-tau

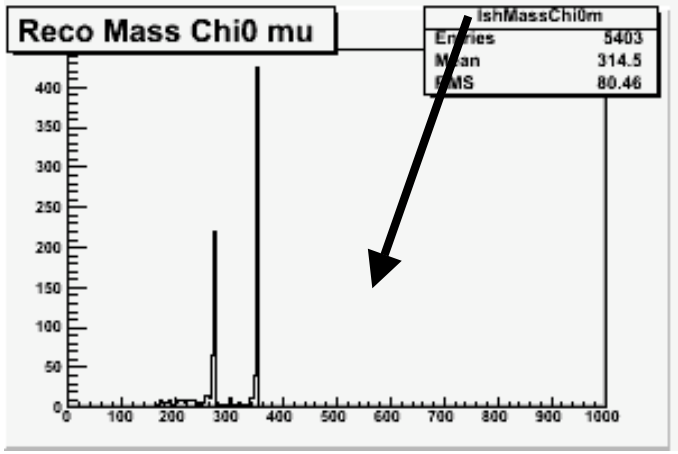
All Processes



Here there is a large contribution at low mass
(due to the kinematics of the 3-body decay)

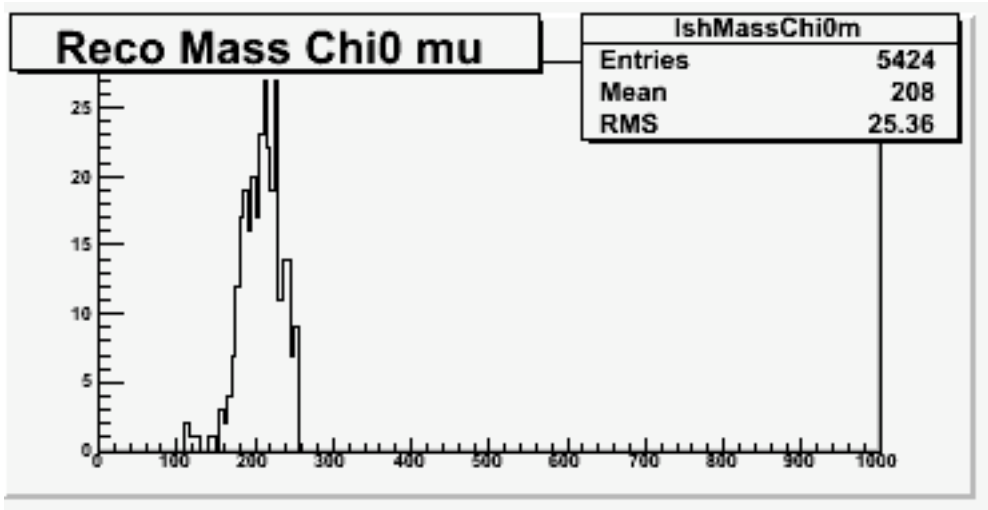


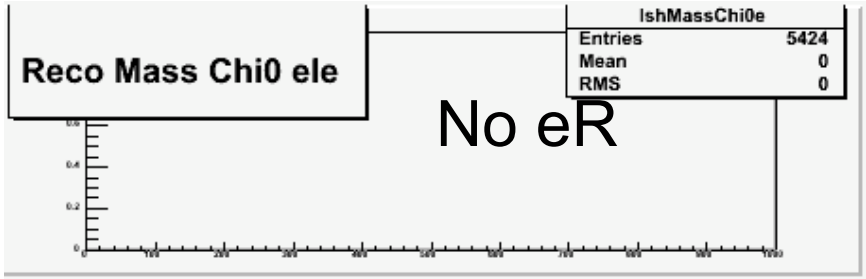
Here we can recognize
the chi02 and the chi03

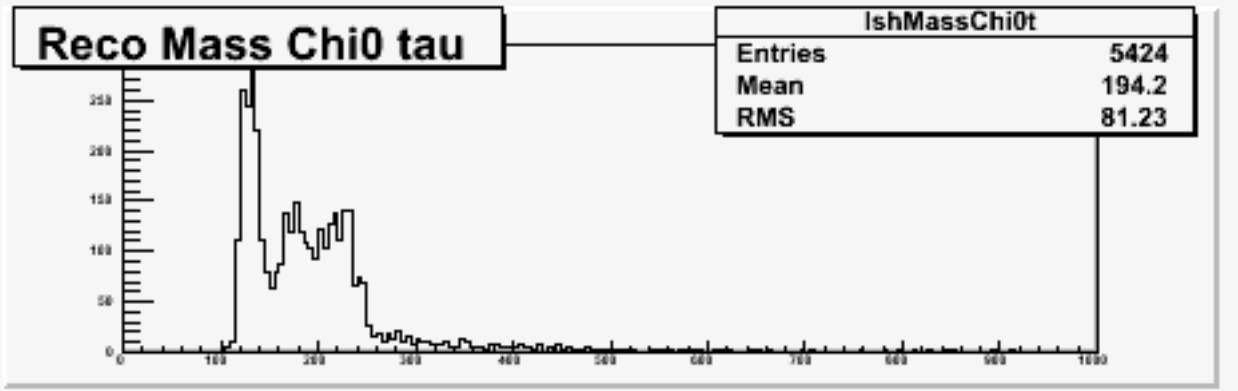


Mass Combinations

Higgs Only sample

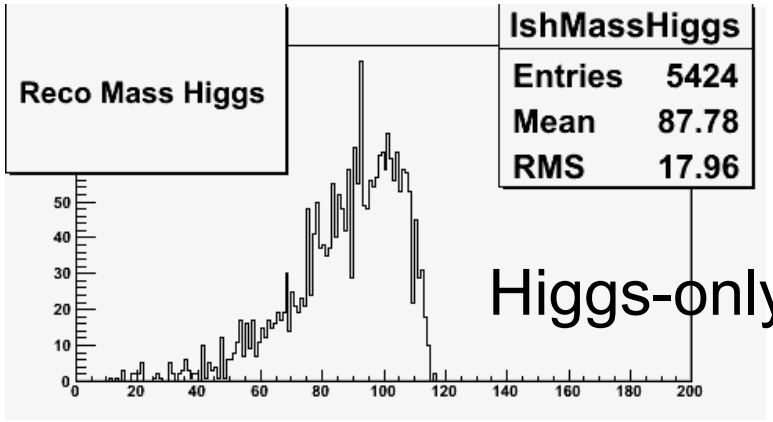




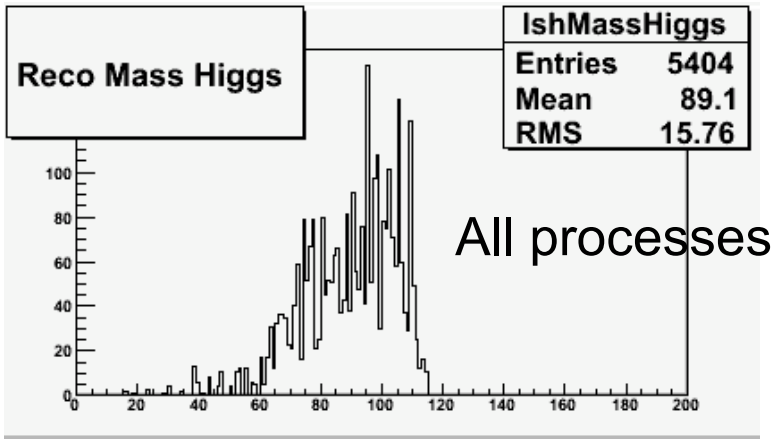


bbar mass

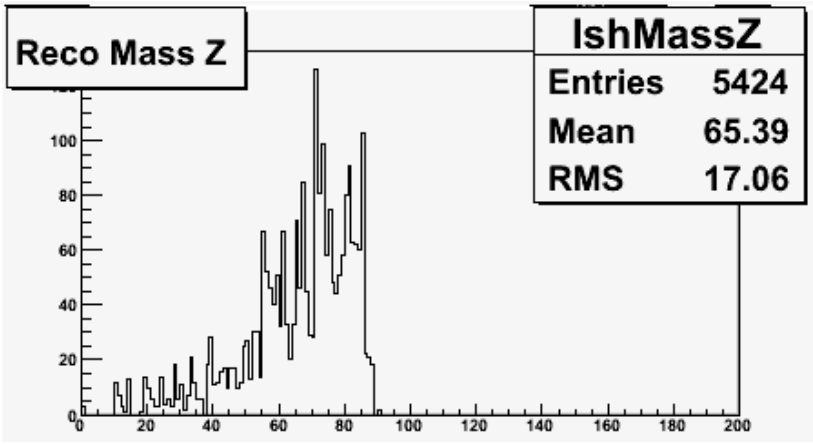
Select a pair of b-bbar with istat code 2
Check their mother ID to be 25 (Higgs) or 23 (Z)
Plot the invariant mass of the bbbar system for events with 2 sleptons and PT(b) > 25 GeV

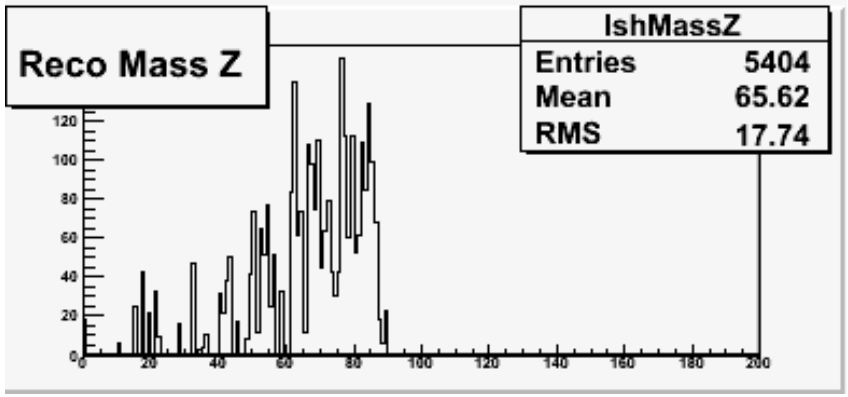


Higgs-only



All processes

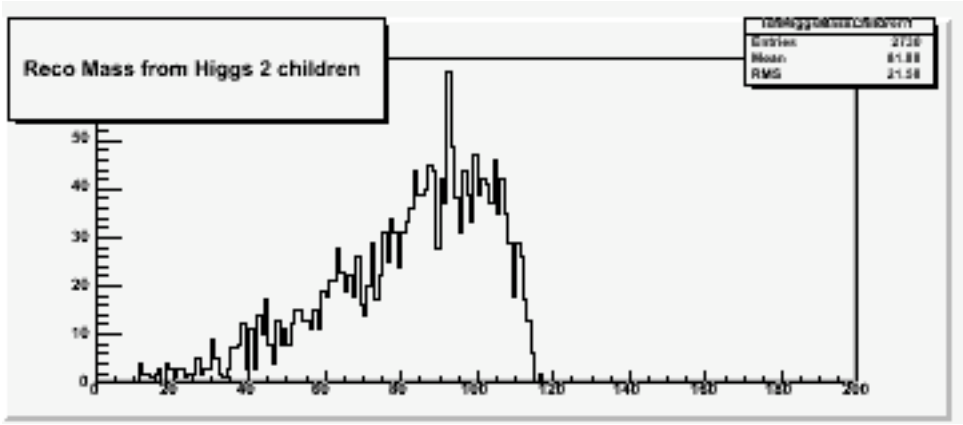




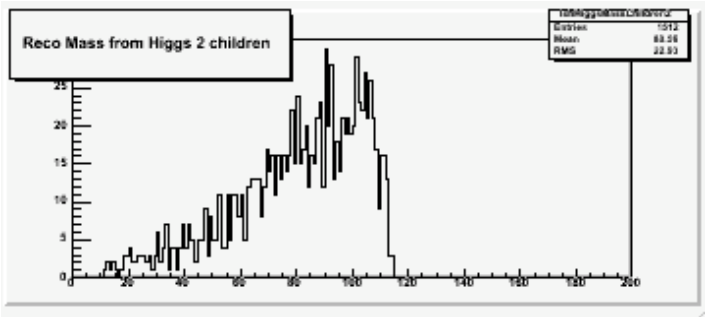
bbar Mass (cont'd)

Select a Higgs and check for its children to select a bbar pair:

- ===Event number 5424 Higgs has 13 children with ID and status of the children
- ID = 5 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = -2 status = 2
- ID = 2 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = -5 status = 2
- ====Event Number 5424 After Loop on nhep, Number of Higgs in this event is 1

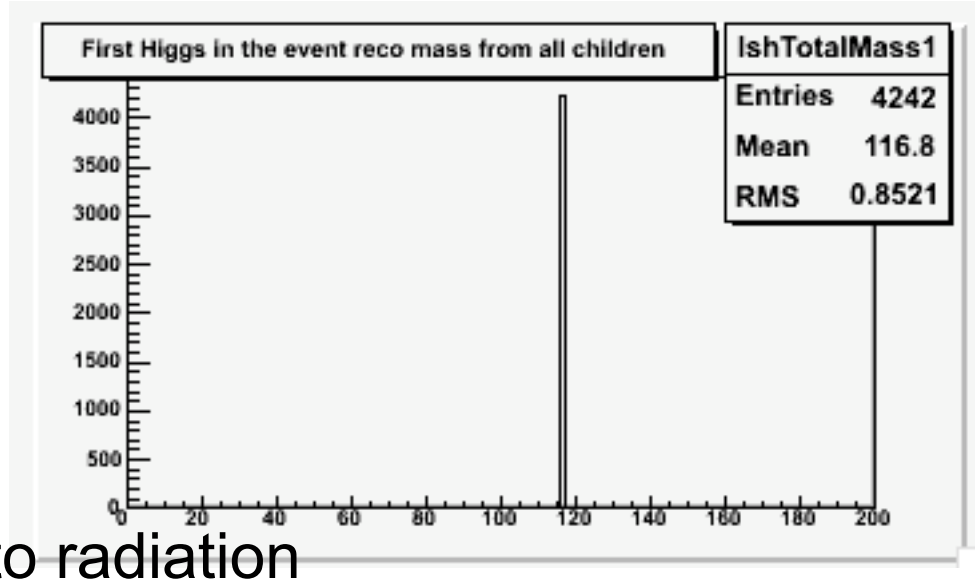


events with 1 Higgs

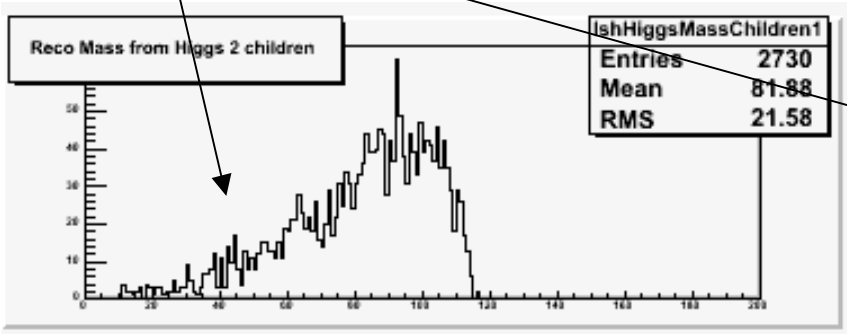


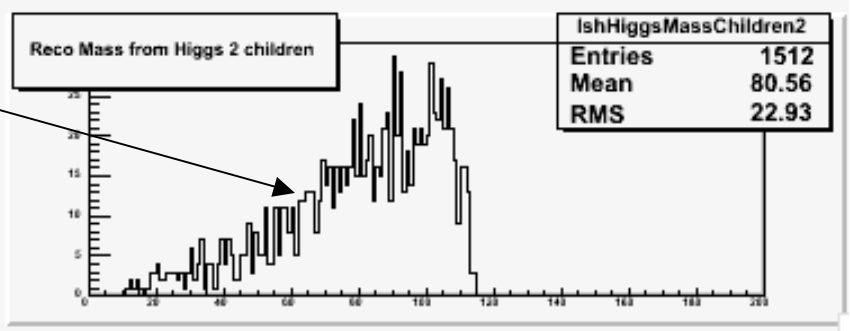
events with 2 Higgses

Bbar Mass from ALL children

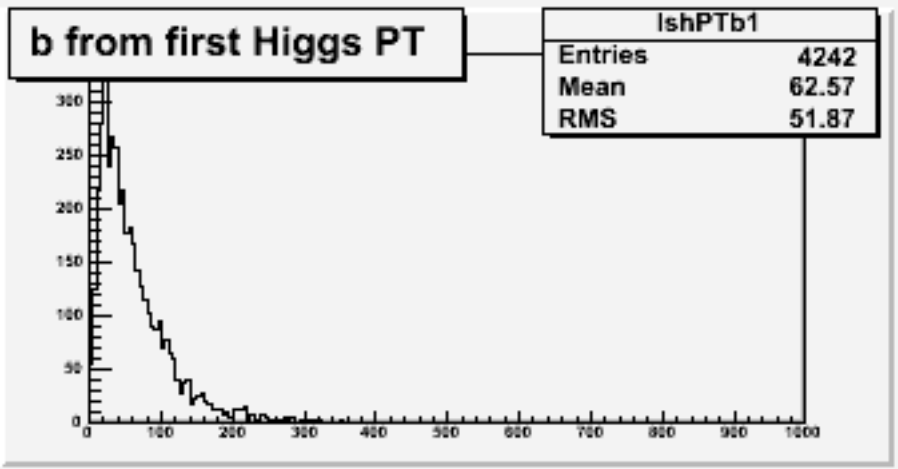


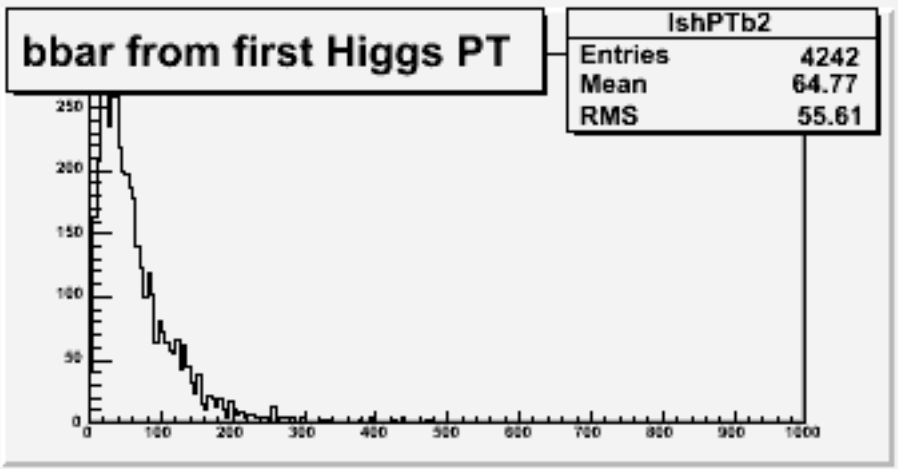
Low tail due to radiation

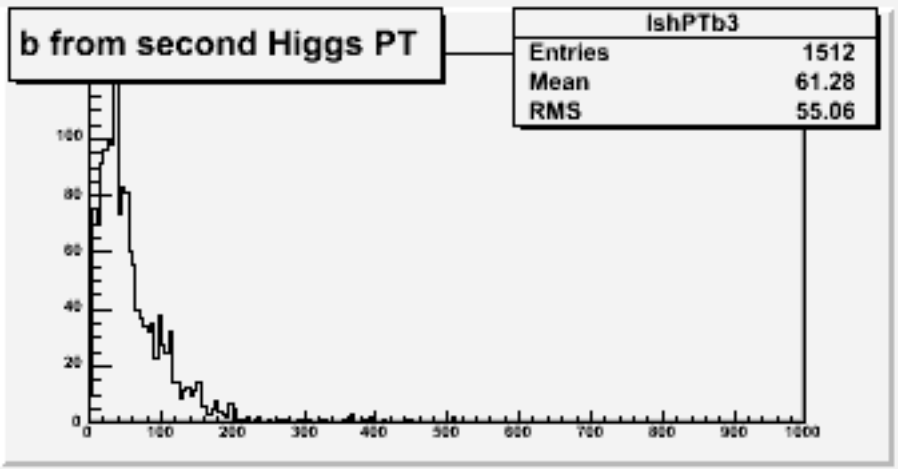


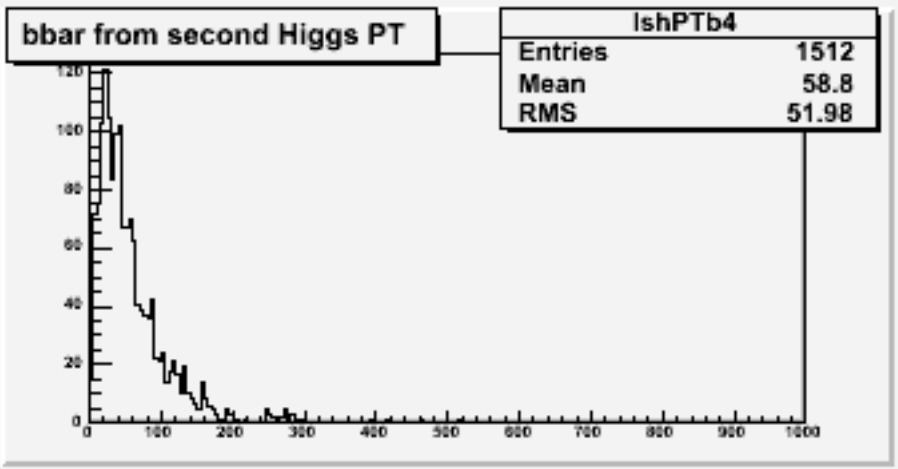


Pt of b partons





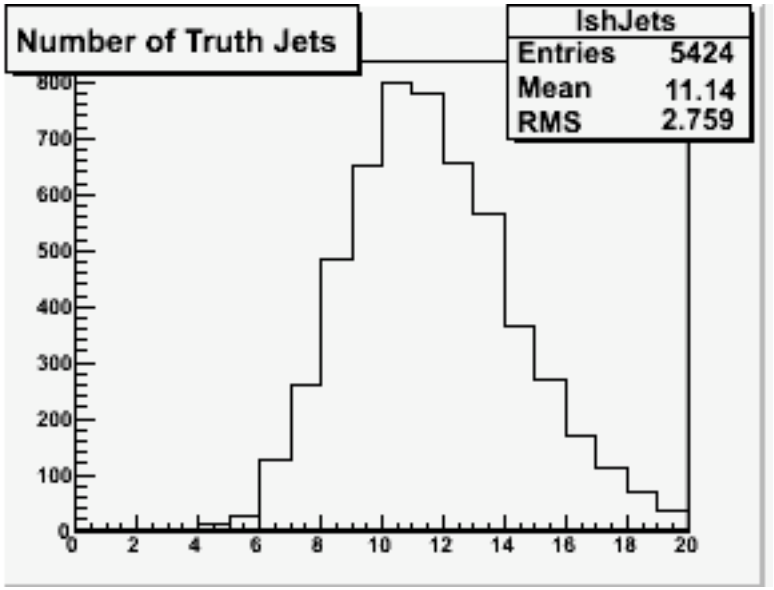




Jets

- At generator level we cannot select light jets, there are too many light quarks and gluons coming from the PS.
- We added a TruthJetCollection for jets of cone 0.4 and 0.7

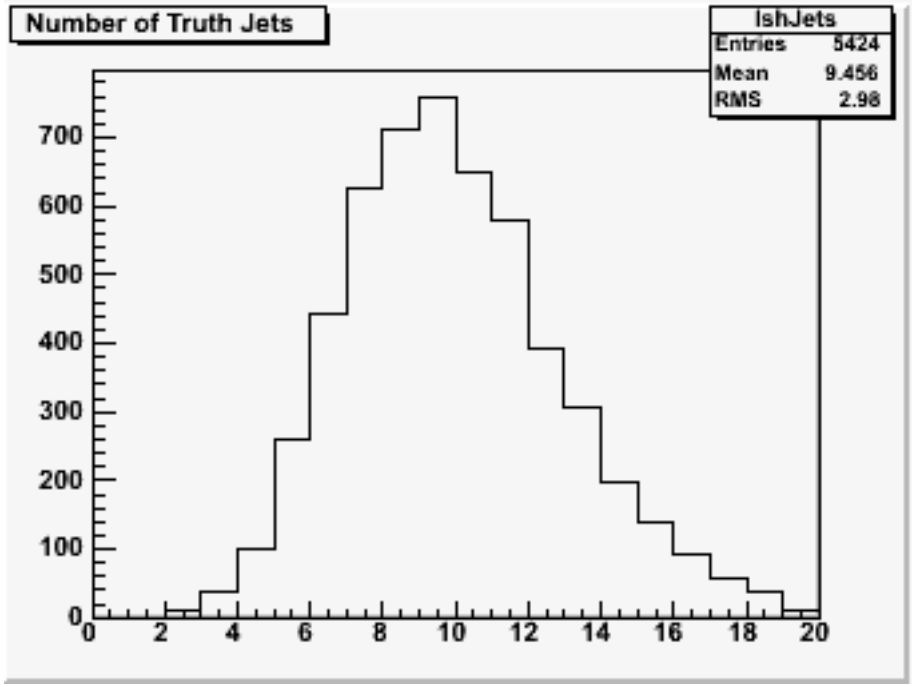
Jet Multiplicities



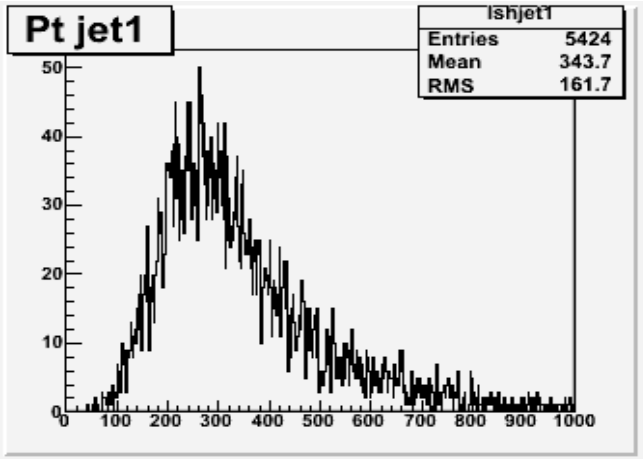
Cone 0.4

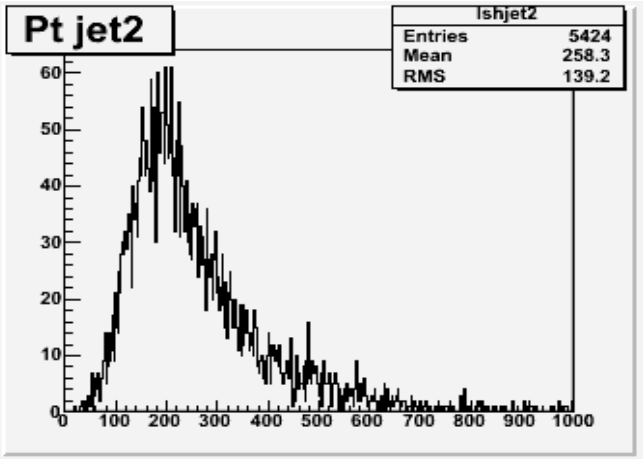
Too high!

Cone 0.7

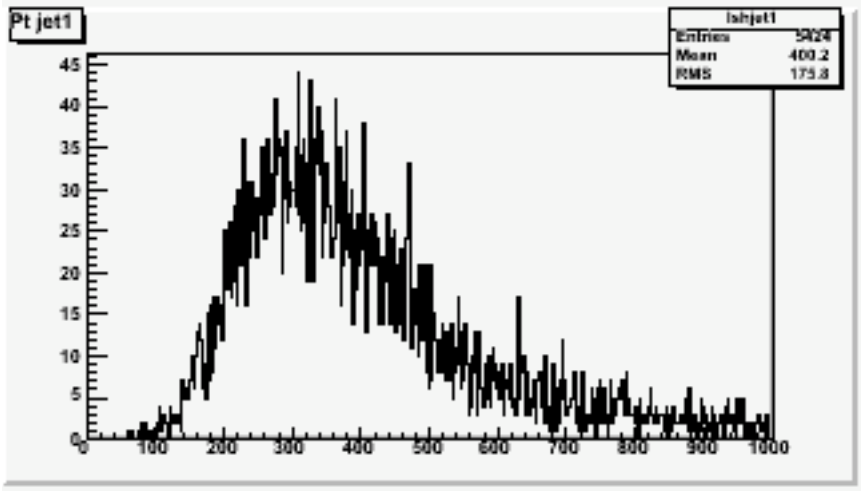


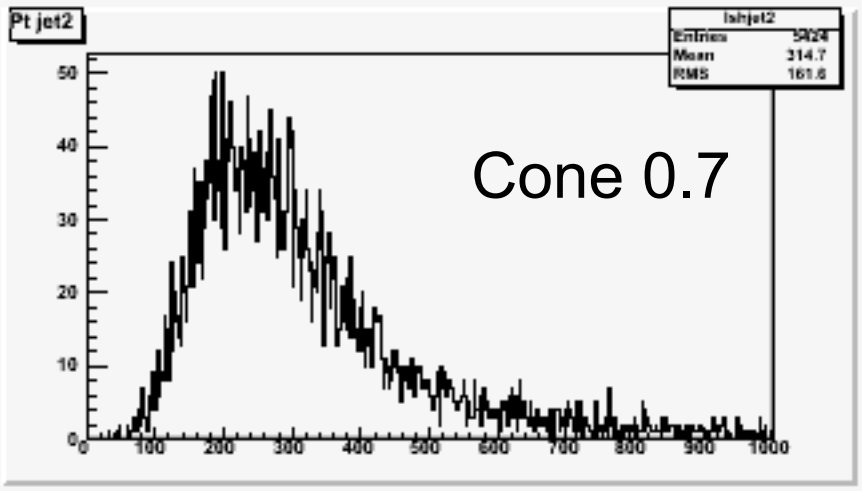
Jets PT





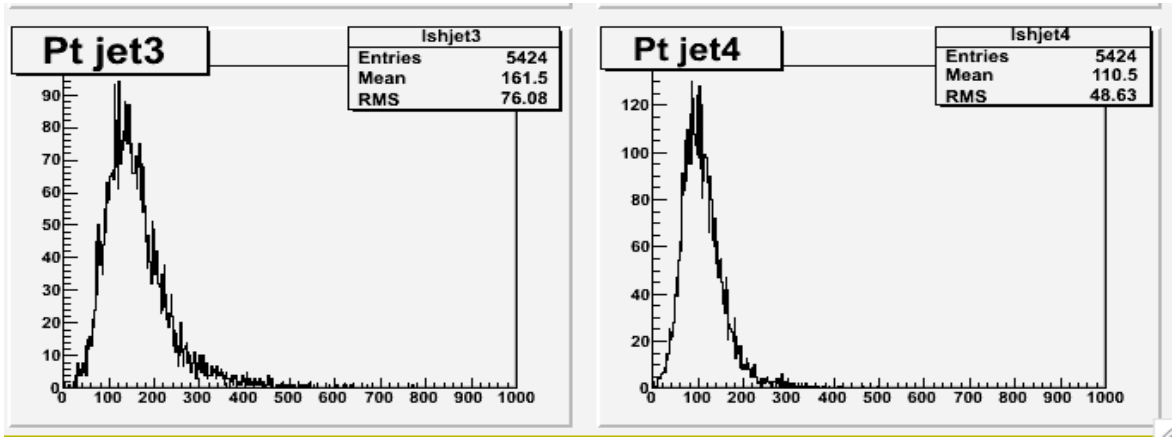
Cone 0.4



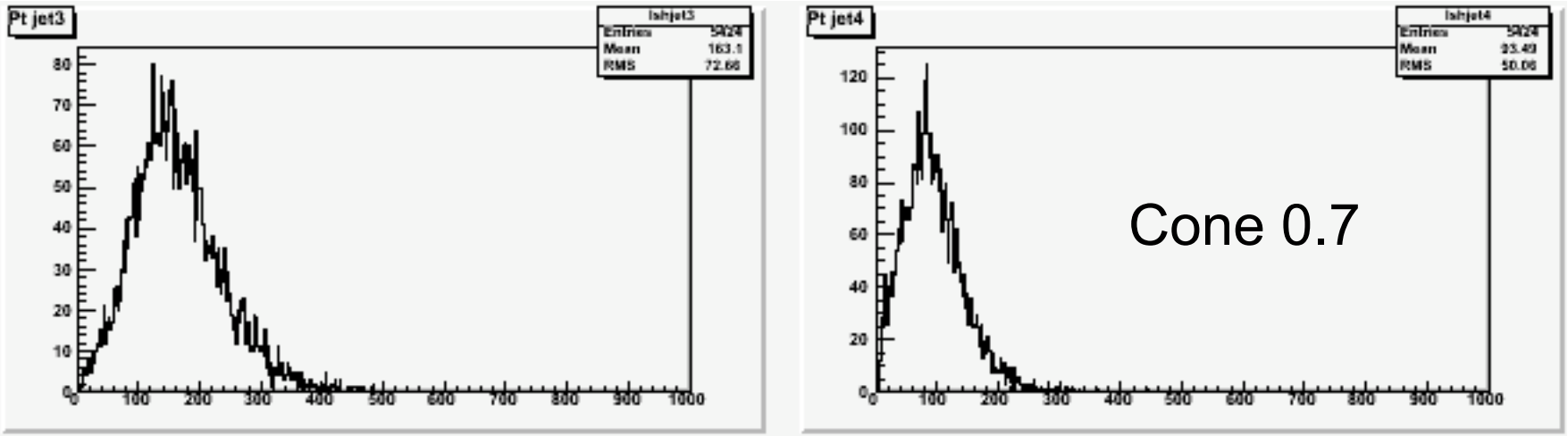


Cone 0.7

Jets PT



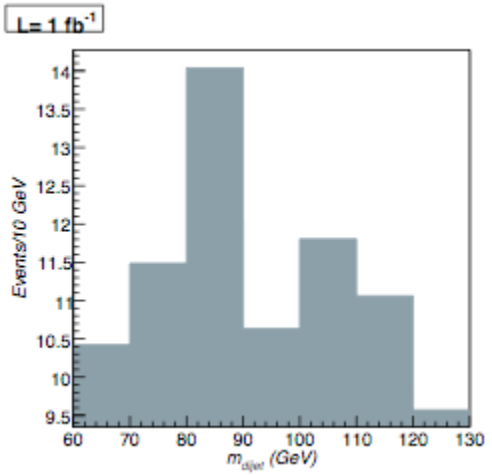
Cone 0.4

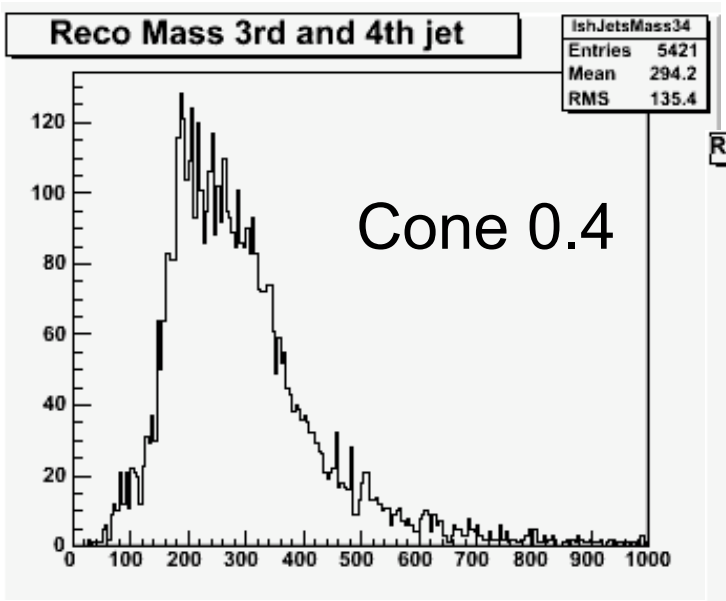


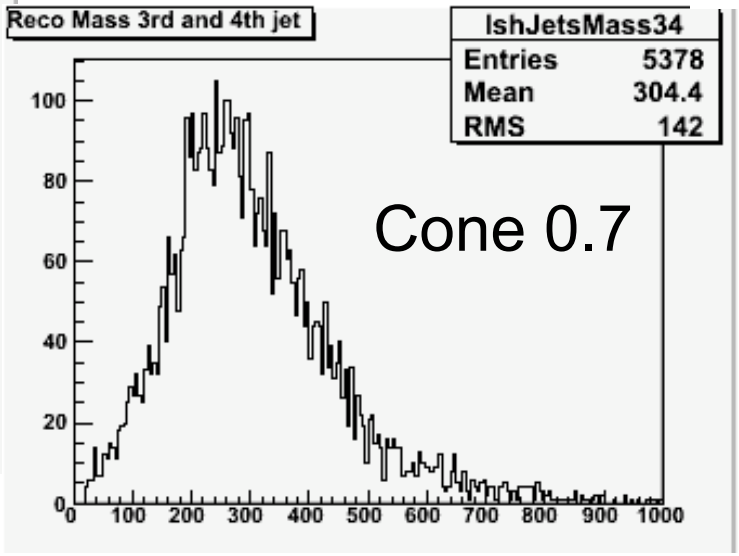
Cone 0.7

Mass Combination jet 3-4

In the theory paper, the authors select events with 1 or 2 sleptons and reconstruct the mass of the 3rd and 4th jet, with PT > 25
Clear Z and Higgs peaks are observed
We tried to reproduce the result….







Obviously something was wrong…

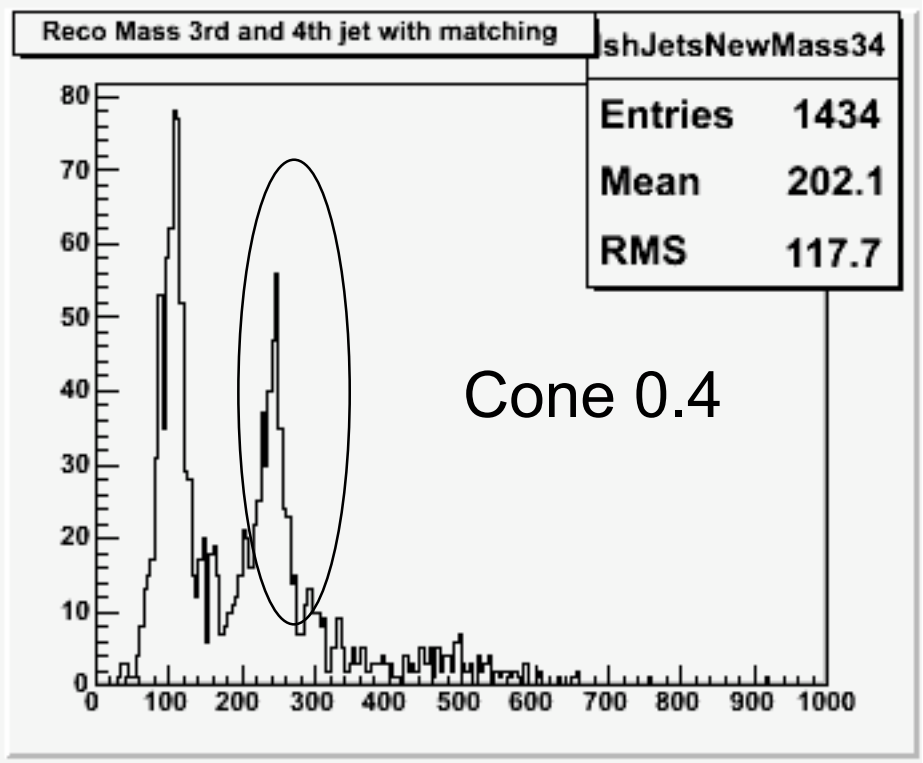
Mass combination of jets matched to b-bbar pair

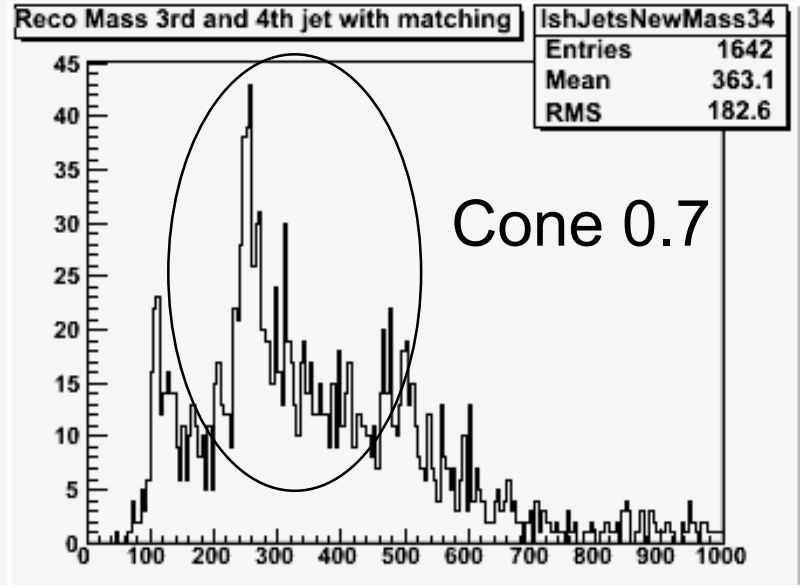
We decided to select jets by associating them to the b-partons;

Events are selected where is only 1 Higgs (for sake of simplicity) decaying into bbar

The jets are associated to the bbar via DeltaR

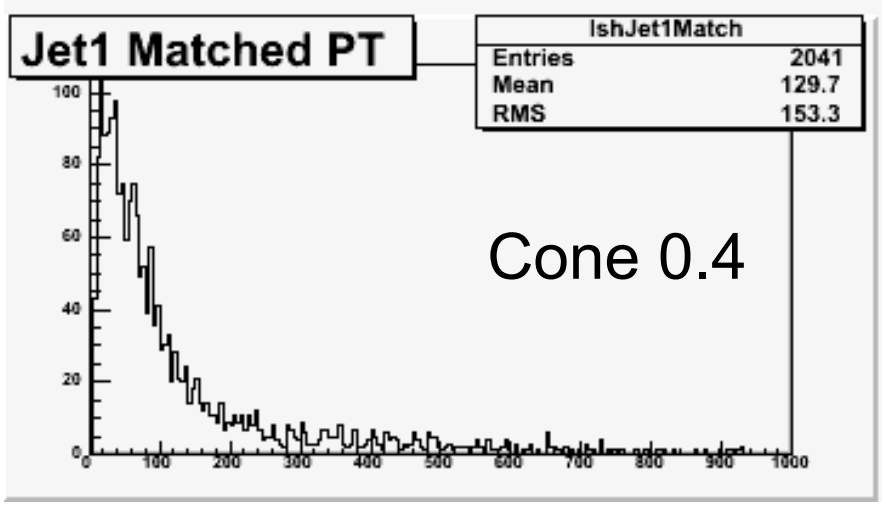
The mass distributions were even more puzzling…

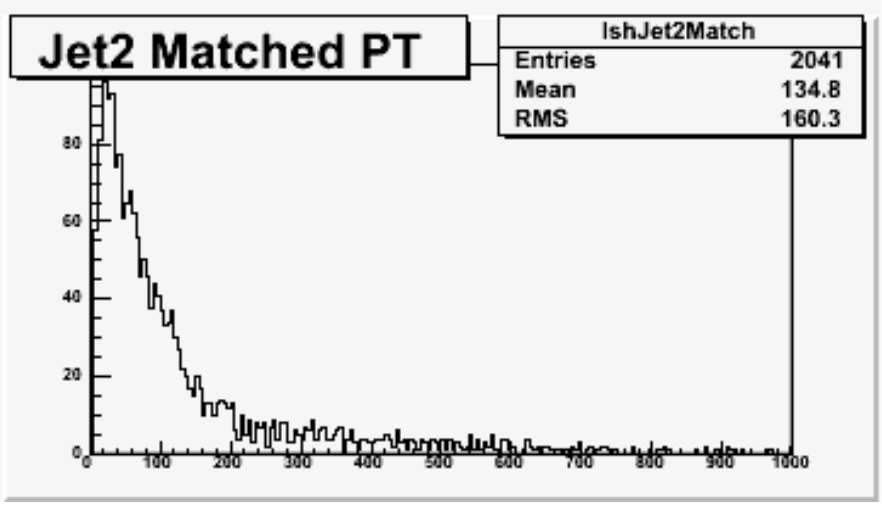


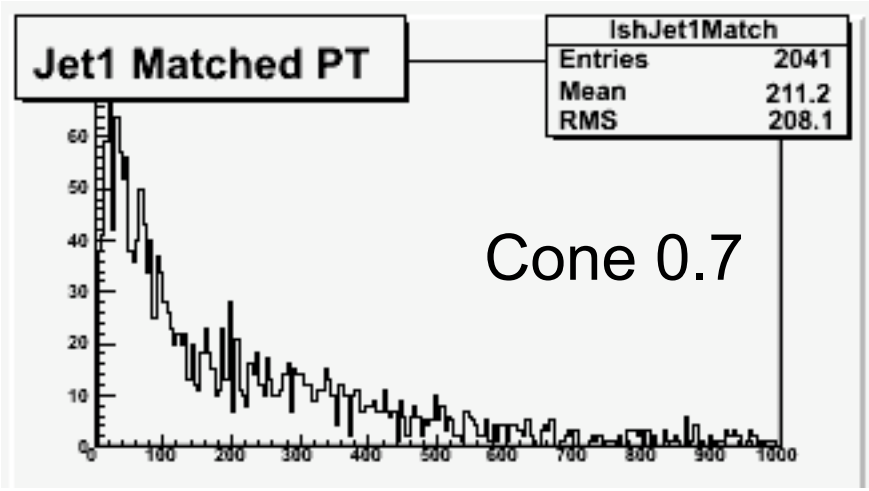


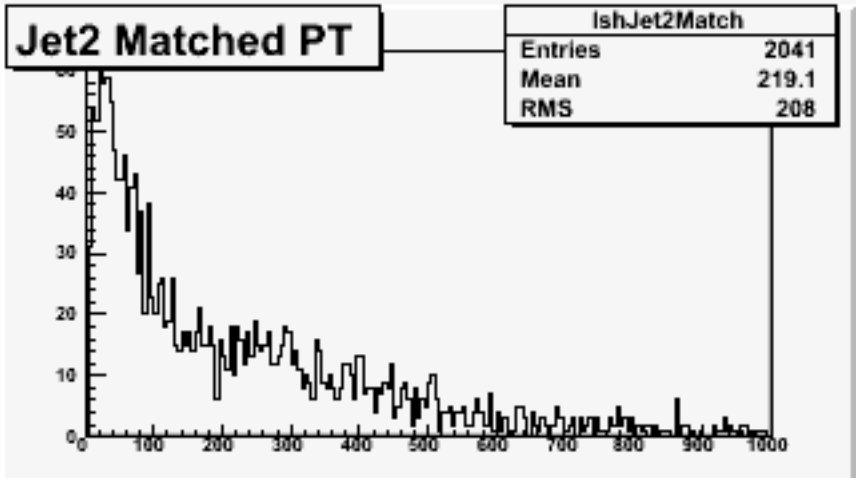
What is the second peak??

Pt of matched jets





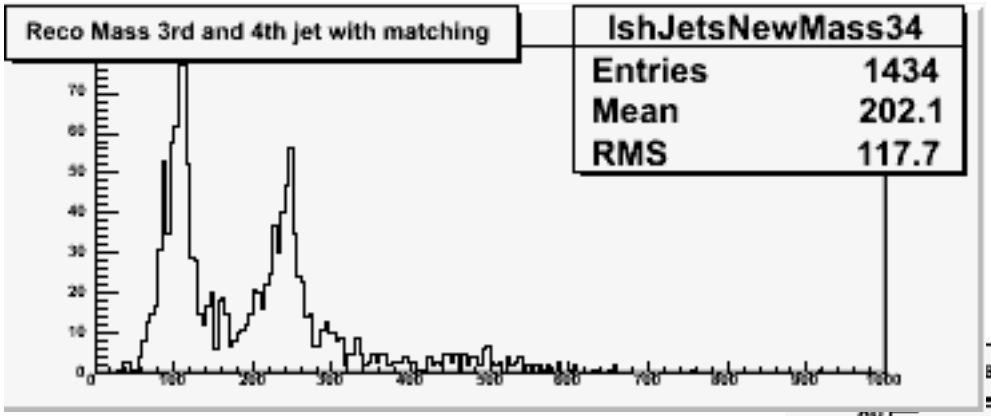




The second peak…

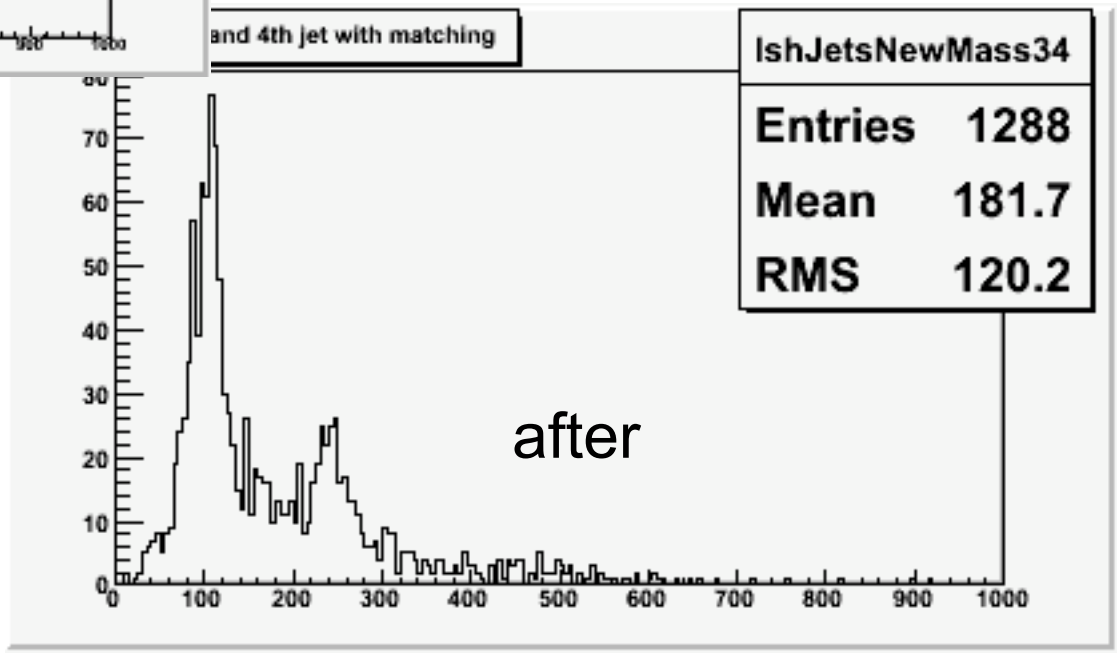
- Hypothesis:
  - The second peak is at the mass of the sleptons…so it could be indeed that TruthJet reconstruction picks the slepton and makes a jet of it…
  - Because of the boost the “slepton jet” is very close to the b’s from the Higgs and gets picked as the closest jet to the b’s.
  - Solution: remove the 2 jets closest to the 2 sleptons in the event and do the Higgs mass reconstruction with the remaining jets using the 2 closest to the b’s from the Higgs..

Removing the jets…



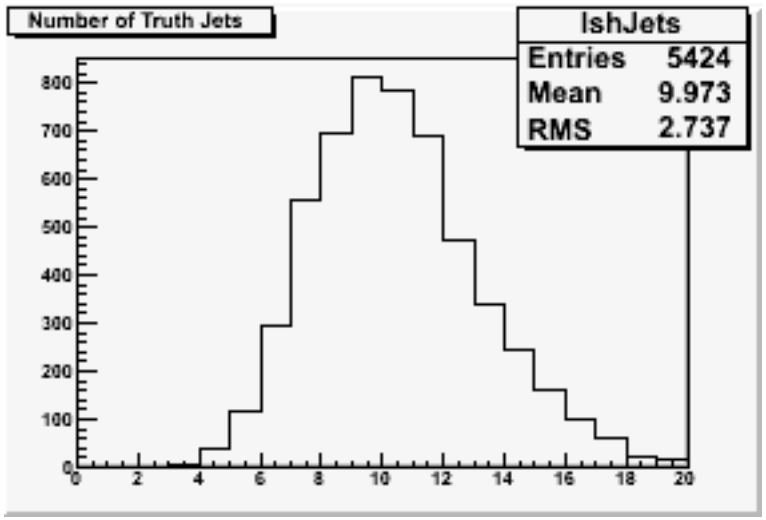
Before removing the 2 jets closest to sleptons

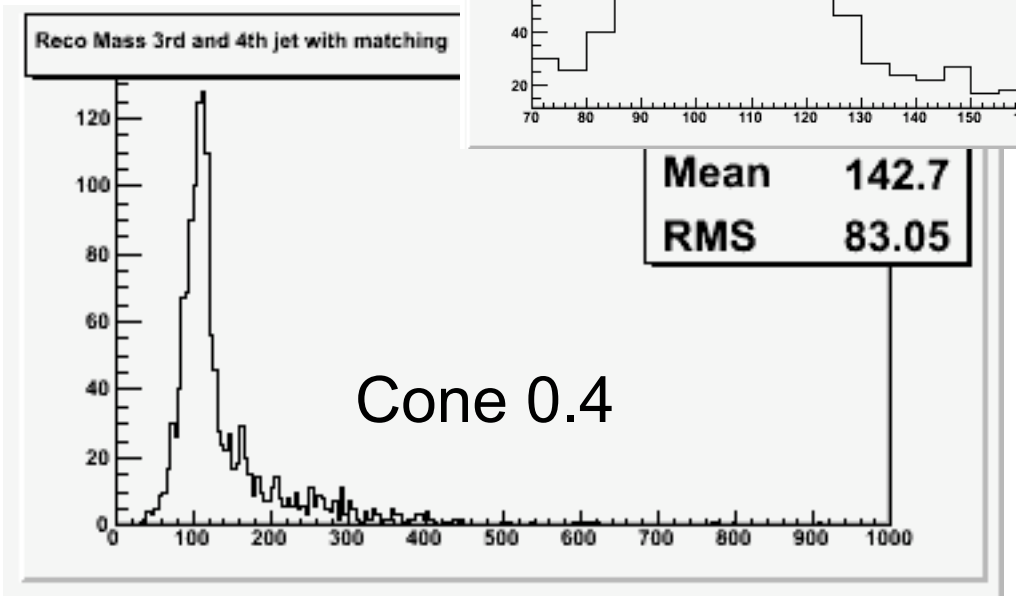
Cone 0.4

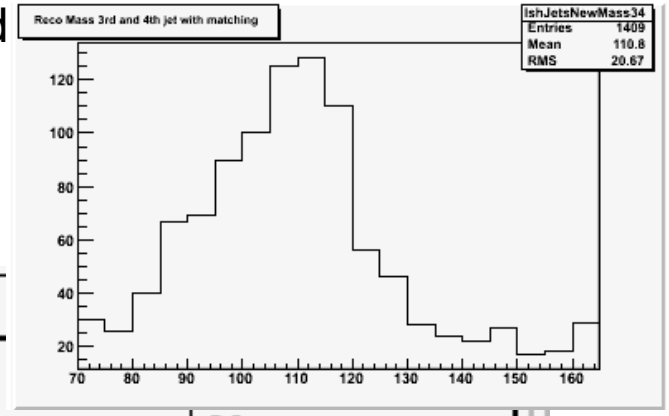


Modified JetTruth

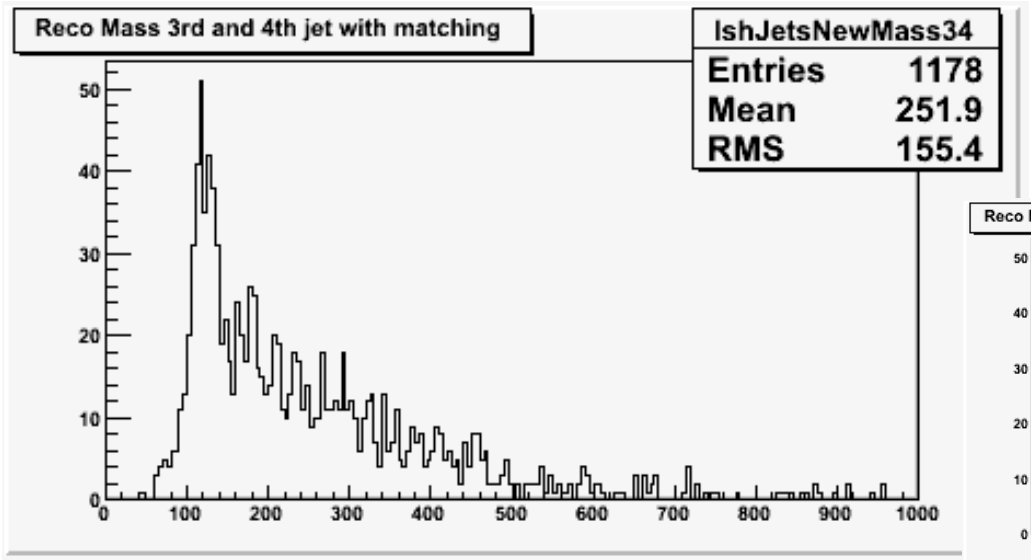
- We modified the stable truth collection before running JetTruthAlgorithm to remove the sleptons from the list of final state particles to be used for jet reco;
- The jets multiplicity and reco Higgs mass should
- And they do!!

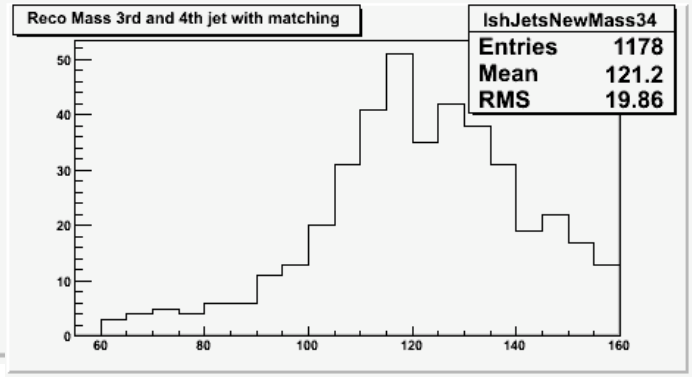


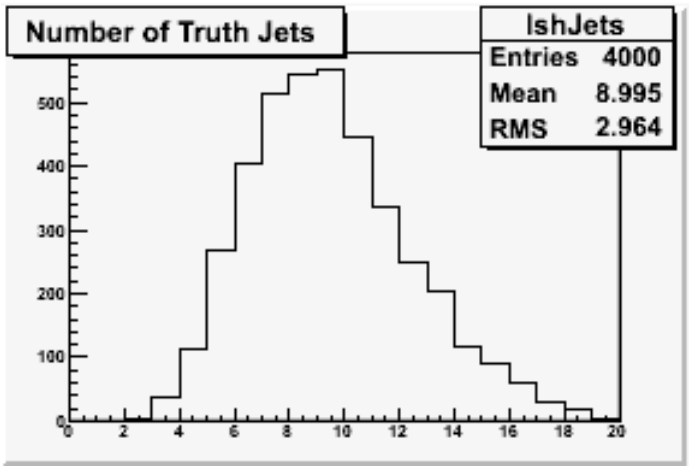




Modified JetTruth 0.7

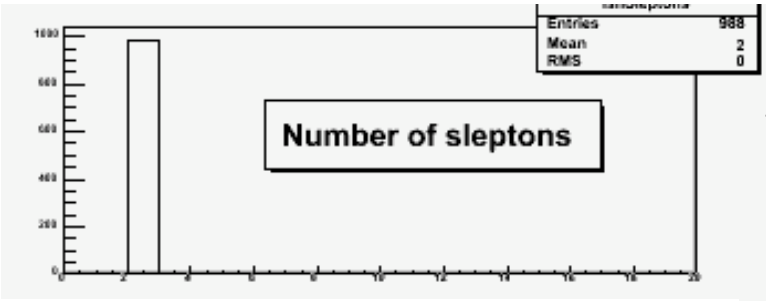


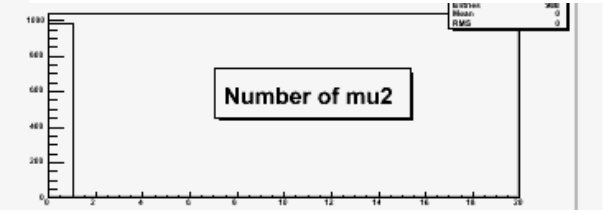


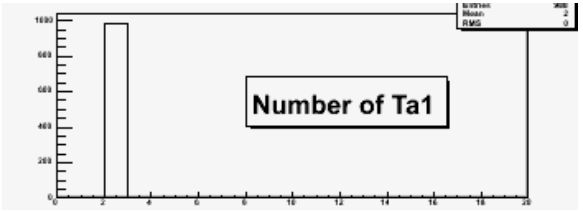


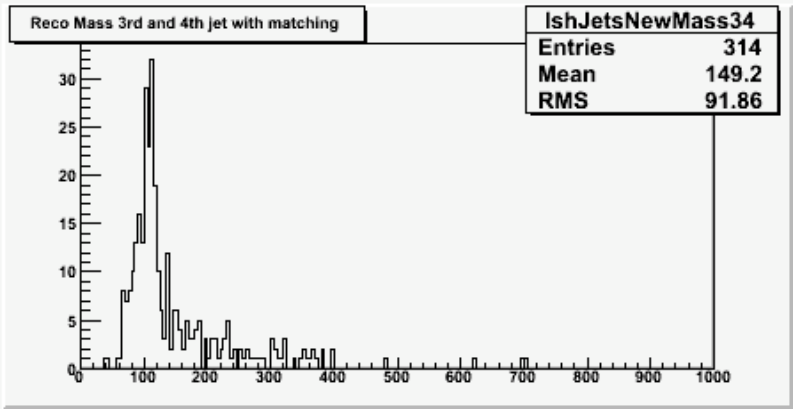
No co-sleptons

- Our final sample will only contain staus in the final state
  - eR and Mu2 will be decayed
- All the previous tests were ran and everything looked ok



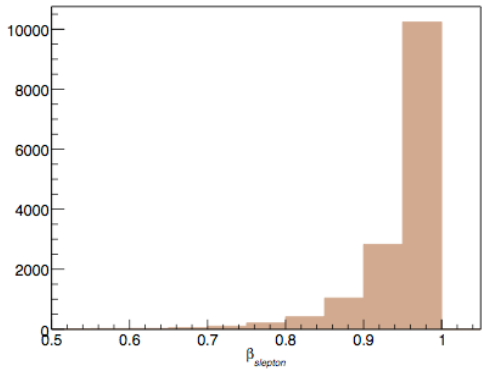






Other Issues

- In the leptogenic scenario the sleptons will behave like CHAMPs, ie slow moving particle crossing the detector with MIP-like signature.
- A challenge in this case will be the correct assignment of bunch crossing;
- Efficiencies to correctly assign the slow-moving particle to BC decreases with β : for $0.8 < \beta < 1.0$ the efficiency is ~80-100%*
  - Most of our sleptons will have $\beta > 0.8$
- Shlomit Tarem and her group are helping us to correctly setup the simulation and reconstruction flags for this process.



* arXiv:0901.0512

Conclusions

- We tested the sample generation of events with Higgs produced in association with letpons and jet in the framework of leptogenic SUSY;
- We would like to submit a formal request for sample generation through the central production facility.